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FIRE WEATHER and BEHAVIOR of the LITTLE SIOUX FIRE

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Rodney W. Sando and Donald A. Haines

Northern Minnesota experienced a period of very severe fire weather during the spring of 1971. Little precipitation fell after mid-April snowmelt and dry, windy weather forced fire danger upward. In mid-May the Little Sioux fire burned 14,628 acres of forest on the Superior National Forest during a 3-day period. This paper documents the fuel and weather conditions that caused this fire to behave as it did.

SETTING THE STAGE

Climatology and Fire Danger Ratings

The Little Sioux, typical of most large fires in this region, followed a period of abnormally dry weather (Haines and Sando 1969). April precipitation was about an inch below normal and only 0.28 inch of rain fell in May at nearby Ely, Minnesota, during the 2 weeks preceding the fire. Normal rainfall during the first half of May is about 1.30 inches. The fire started on May 14. The last significant rainfall occurred May 4 when 0.12 inch fell (table 1). The Buildup Index (BUI), according to the National Fire Danger Rating System (Nelson 1964), was 45 on the day of the fire, which is much above the average of 25 for this date (Sando 1969). The Danger Rating System's Fire Load Index (FLI) was 93, well into the extreme range. From 1936 to 1970 only 5 days had a FLI higher than this at Ely. The fire danger on May 14, therefore, was unusually critical, even though this is normally the most dangerous period of the year (fig. 1).

Table 1. — *Weather and fire danger rating observations at Ely, Minnesota, 1971 (1300 c.d.t.)*

Date (May)	Temperature	Relative humidity	Precipitation	Wind direction	Wind-speed	BUI	FLI
	°F.	Percent	Inches		M.p.h.		
1	41	84	0.07	NE	10	6	1
2	52	25	.07	N	10	9	11
3	60	23		N	4	12	7
4	58	57	.12	NE	4	11	3
5	54	49		NE	8	14	7
6	64	20		SE	4	16	8
7	69	22		NW	9	19	17
8	56	26	T	SE	3	22	6
9	71	15		S	6	27	20
10	75	19		N	6	32	20
11	44	44	.02	NE	13	34	29
12	56	17		NW	10	37	32
13	60	23		NE	11	40	49
14	76	15		SW	16	45	93
15	59	53	.01	SW	11	47	24
16	68	24		NW	8	50	41
17	60	89	.10	SW	10	50	5

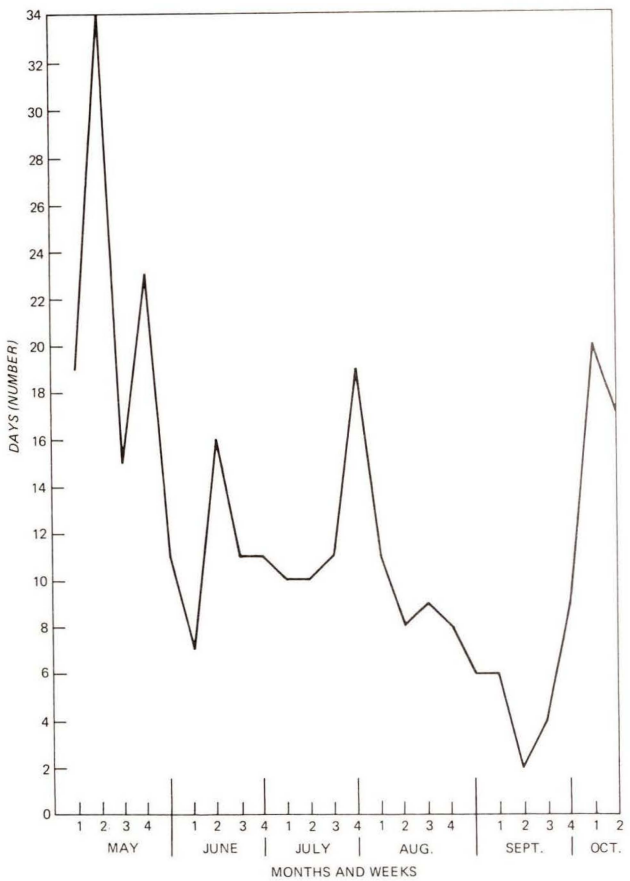

Figure 1. — *Frequency of occurrence of class four, fire-danger (very high) days at Ely, Minnesota, during 1936-70, grouped by weeks.*

Topography

The area burned by the Little Sioux fire is flat to rolling, containing numerous swamps between the low ridges. These ridges are rocky ledges without a uniform pattern. The topography therefore had little influence on the behavior of the fire; however, the

boggy areas between the ridges were wet, making vehicular travel difficult — sometimes impossible.

Fuels

About 65 percent of the area burned had been recently logged. Some of the fuel on these logged areas had been partially reduced by prescribed burning. The fire spread rapidly in the open, cutover areas largely because there was little obstruction to winds. Almost all the logged areas are located in the southern portion of the fire region and account for most of the fuel type near the point of ignition. Unburned slash and burned slash areas are rated H-M[1] and M-H, respectively, for springtime conditions (USDA Forest Service 1938).

A small part of the burn area had been planted to red pine and white spruce following the logging operations. All the plantations were no older than 10 years and also rated H-M.

The remainder of the fire area contained several different vegetative and fuel types. The more important types and their ratings are (USDA Forest Service 1938):

Mature aspen stands	L-M
Aspen-birch with coniferous understory	L-M
Mature jack pine stands	L-M
Lowland black spruce stands	L-M
Pure balsam fir stands	L-M
Tall grass marsh	E-M
Balsam fir stands recently killed by spruce budworm	M-H

Throughout the burned area there was dead balsam fir resulting from the spruce budworm outbreak of the early 1960's. The dead material made line construction difficult and provided a convenient bed for the ignition and spread of spot fires (fig. 2). The dead fir may not have greatly influenced the advance of the main flame front, but it certainly did interfere with suppression efforts.

Figure 2. — *Fire behavior in balsam fir that was affected by earlier spruce budworm attack.*

Much of the fuel in the area was tall grass marsh. This fuel type is conducive to rapid spread and was partly responsible for the large size of the initial fire run, particularly in the southern sectors. Lowland black spruce was the only fuel type that did not burn well, probably because of the wetness of the low areas, the result of spring snowmelt.

Synoptic Weather

Three periods of weather greatly infuenced the behavior of this fire. All three periods involved frontal movement coincident with major fire runs.

A fast-moving frontal system passed over the Little Sioux area early on the night of May 14 (fig. 3A). Ahead of and with it associated weather spurred the fire's early afternoon start as well as its greatest spread. Dry air prevailed to the east of this system and had covered the region for 2 days previous to the fire. Early afternoon relative humidity readings were in the teens and low 20's at Ely on May 12 and 13, with overnight rises to 55 percent. This low diurnal humidity range, coupled with brisk afternoon winds, intensified fuel drying.

Late afternoon upper-air soundings at nearby International Falls and St. Cloud, Minnesota, on the 14th showed a highly unstable atmospheric layer in the first 350 feet above surface. A conditionally unstable temperature lapse rate prevailed above this to 10,000 feet.

[1] *Letter designations indicate rate of spread and resistance to control. The ratings are L—low, M—moderate, H—high, and E—extreme. As an example, L-M represents a low rate of spread and a moderate resistance to control. Spread rates in chains per hour would average about 10 for a letter designation of L, 20 at M, 40 at H, and 80 at E.*

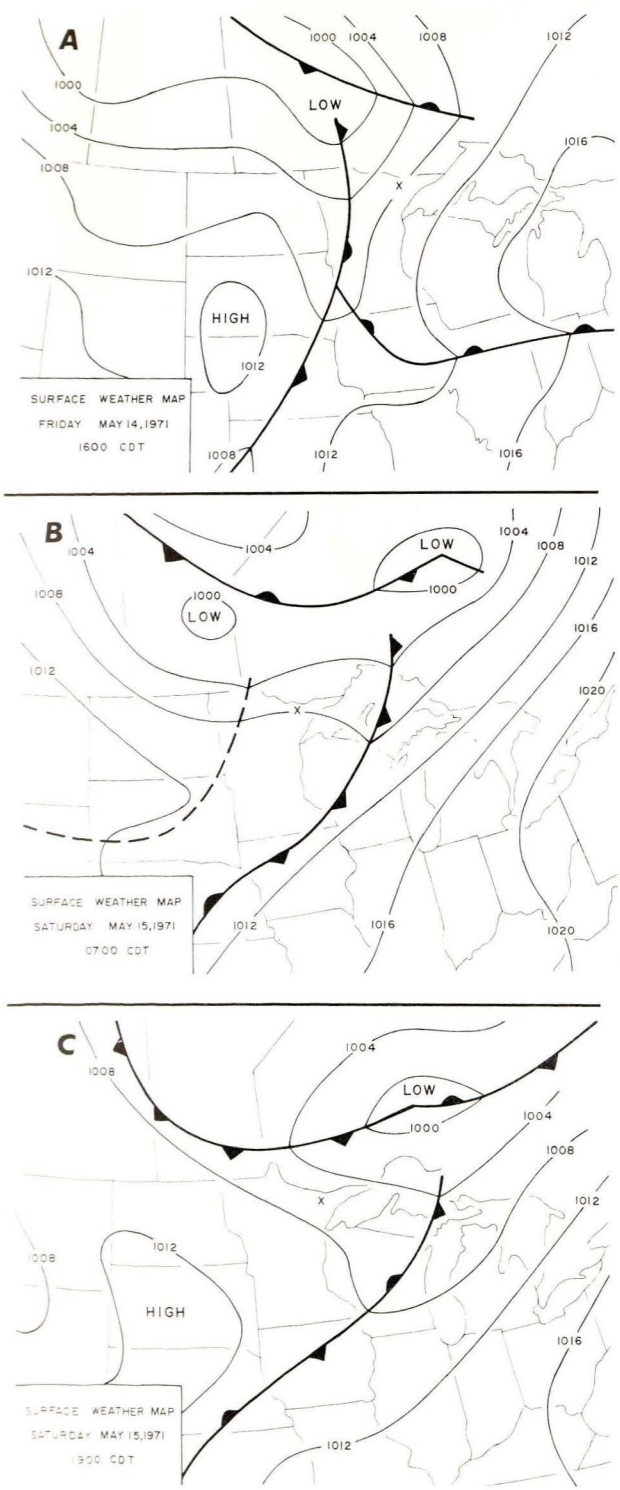

Figure 3. — *Surface weather features occurring (A) during the period of initial attack and the first fire run, (B) before the second major fire run, and (C) during the third major fire run. An "X" designates the fire location.*

Early evening winds were strong southwesterly ahead of the fast-moving frontal system, although a wind shift to the southeast in the fire region occurred 45 minutes before the 2045 c.d.t. frontal passage. It is not clear whether this southeast shift was fire induced or the result of an anomoly in the large-scale, isobaric pressure pattern. Obviously, the fire-fighter's rule-of-thumb that wind shifts clockwise within a frontal system is not infallible. Nature, unfortunately, does not always follow the classical model.

The morning weather map on the 15th (fig. 3B) shows a surface pressure trough well into western Minnesota, following about 300 miles behind the main frontal system. This secondary impulse moved rapidly eastward under upper-level, zonal flow and, associated with high vorticity values, produced general cloudiness and a few scattered showers in northern Minnesota. This trough brought increased windspeeds, causing the second major fire run during the morning of the 15th.

A stationary front stayed well north of the Canadian border during the eastward movement of the described system. However, as the secondary impulse later consolidated with the main system and slowed in eastern Wisconsin, the Canadian front sagged slowly southward (fig. 3C). Sufficient cool air moved in behind it to change its designation to a cold front. This Canadian front moved southward to the U.S. border, causing brisk west to north-northwest winds ahead, with a sharp shift to the northeast behind. These prefrontal winds caused the third major run. This cold front did not move southward over the fire, but its close proximity during late afternoon and early evening on Saturday presented meteorologists with a difficult weather forecast decision. Weather conditions and accompanying fire behavior patterns could have been quite diverse, with only small changes in the movement of the front.

CHRONOLOGY

Friday, May 14

A routine aircraft patrol detected the Little Sioux fire at 1330, approximately 50 miles southeast of International Falls, Minnesota, and 2 miles from an all-weather road. It was a holdover from a prescribed burn of April 26. The weather conditions at the time of detection were: temperature 76° F., relative humidity 15 percent, and winds southwest at 16 m.p.h.

with gusts to 20 m.p.h. Because the fire started in an open area where slash was recently burned it did not spread rapidly until it moved beyond this fuel type.

Escaping initial attack, the fire reached unburned fuel about 1615 and began to spread rapidly with the strong southwesterly winds. Hourly observations taken at International Falls showed the wind increased from 15 m.p.h. at 1300 to 23 m.p.h. at 1600.

Rate of spread increased dramatically when the fire reached the previously unburned area. The main fire front reached the Echo Trail road (fig. 4), about 2 miles from the point of origin, at approximately 1745. Crowning became widespread, and a large spot fire was observed approximately half a mile north of the road at that time. Long-range spotting was generally due to the high winds, low fine fuel moisture, and the prevalence of slash and spruce budworm-killed balsam fir that provided fuel for easy ignition and

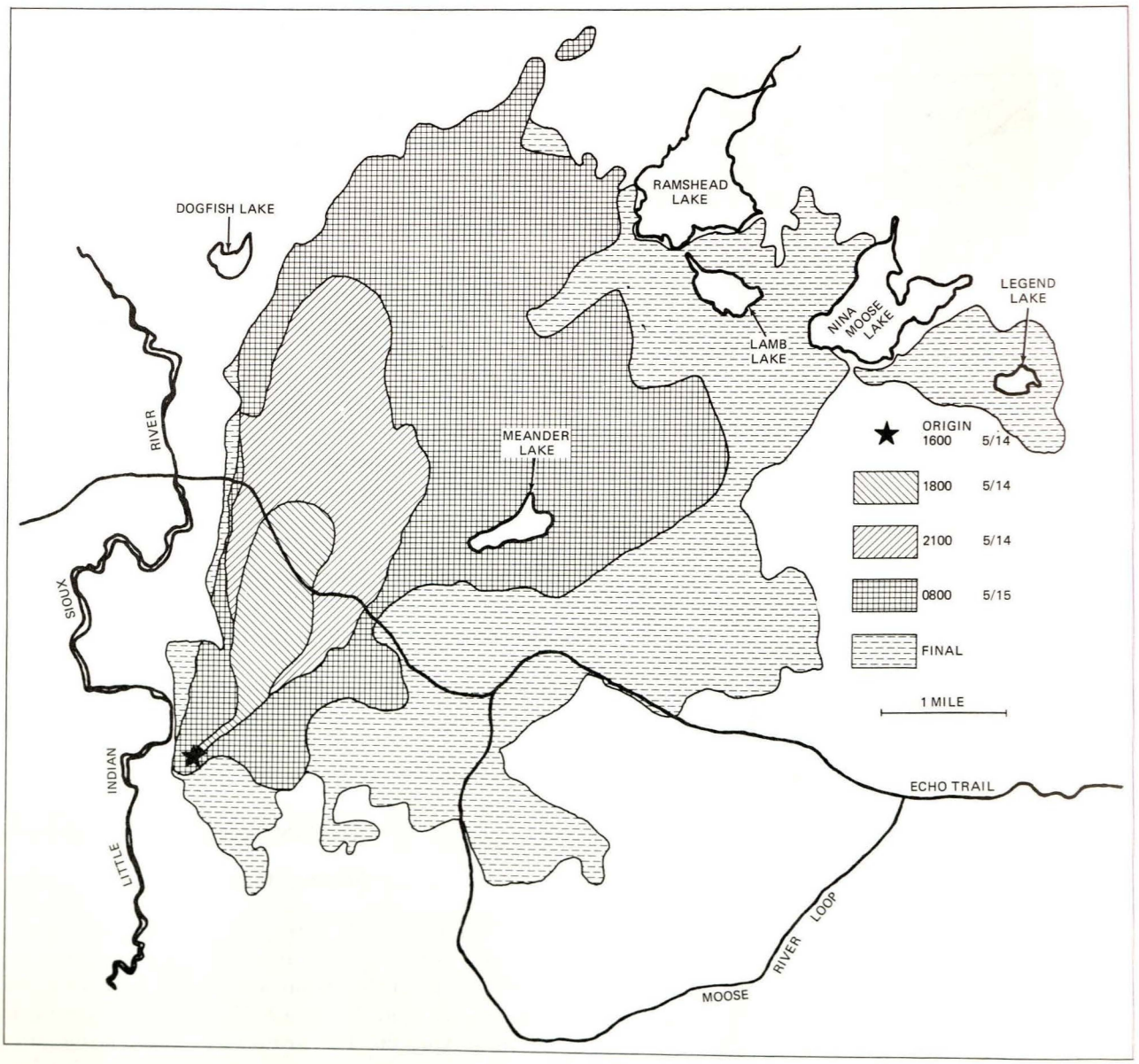

Figure 4. — *Estimated perimeters and gross areas burned at selected times during fire.*

rapid spread. The main flame front moved forward at about 1.2 m.p.h., and the extensive spot fires contributed greatly to the total burning area (fig. 5). Barriers such as roads, trails, and spruce swamps were easily crossed and hence the fire spread was essentially unimpeded.

Figure 5. — *Spotting well in advance of the main flame front.*

The fire moved in a north-northeast direction, and at approximately 1800 aerial observers reported that the burning area had the typical cigar shape of a fast-moving fire in flat topography (fig. 4). The burning area was about 3 miles long and ½ mile wide. The fire was greatly influenced by the presence of the cold front to the west: associated south-southwest winds averaging 20 m.p.h. and gusting to 30 m.p.h. caused the rapid spread during the first 6 hours. About 2000 the wind shifted to the southeast and the fire began to burn in a northwesterly direction along the west flank. This wind direction persisted for approximately 45 minutes before returning to the southwest. A gradual wind shift began toward the northwest as the front passed. The fire then burned toward the east and moved about 2 miles before stopping about 0100 on May 15 (fig. 4). A short, light drizzle at 0200 stopped fire spread for the remainder of the night.

This first major run was the most severe behavior observed on the fire. Long-distance spotting was common up to three-fourths of a mile ahead of the flame front that moved 7 miles in about 6 hours. The fire reached perhaps 60 percent of its final size during this first run.

Saturday, May 15

The second significant run occurred on Saturday morning. With the approach of the secondary pressure trough (fig. 3B), winds began to increase about 0900. At 0930 the temperature was 65°, relative humidity 37 percent, and the winds west-southwest at 10 to 15 m.p.h. with gusts. Responding to these stronger winds, the fire began to spread toward the east. The secondary pressure trough passed over the fire area about 1100 and 0.05 inch of rain fell during the next hour. This light shower wet the fine fuels and stopped the fire spread; consequently, only 5 percent of the total fire area was burned at this time.

A cool, dry, Pacific airmass moved in behind the secondary trough. At 1400 at the fire site temperature was 70°, relative humidity 22 percent, and winds from the north-northwest at 15 to 20 m.p.h., gusting to 25 m.p.h. The morning's light rain had stopped significant forward spread of the fire, but in the afternoon low relative humidity and strong winds caused the fuels to dry quickly, and by 1700 the fire began a third major run. Consequently, at this time the southeastern sector of the fire expanded greatly, although spread was not as rapid as it had been the previous day. The flame front moved forward at about 0.6 m.p.h. compared with about 1.2 m.p.h. on Friday evening.

This third run was caused by strong north-northwest winds generated by the southern movement of the Canadian cold front (fig. 3C). This run continued until about 2100 when the wind velocity decreased and the fine fuel moisture increased, due to lower temperature and higher relative humidity. The fire burned about 25 percent of its final size during this 4-hour period.

Sunday, May 16

Fire behavior on this day was relatively mild compared with that of the previous 2 days. At 1500 temperature was 73°, relative humidity 18 percent, and wind northwest at 5 m.p.h. Fortunately, the winds remained very light throughout the day. The fire did not make a significant run, although isolated areas of unburned fuel within the perimeter burned. About 10 percent of the final fire acreage burned on this day, the last period of significant fire spread.

At 0630 on the morning of May 17, a squall line preceding a front moving in from the west passed over the fire area and by 0800 produced one-fourth of an inch of precipitation. This shower and subsequent precipitation essentially stopped the fire.

SUMMARY

The extreme fire behavior exhibited by the Little Sioux fire was the product of a number of factors. Antecedent, abnormally dry weather caused mild drought across a large portion of northern Minnesota during a time of year when vegetation is still in the cured stage. Friday, May 14, was one of the most severe fire-weather days experienced in the history of the Superior National Forest. The spread of the fire was enhanced by extensive cutover areas and grass marshes conducive to very high or extreme rates of spread. Spot fires were a significant problem; their ignition and spread were greatly assisted by the dead fuels remaining from the spruce budworm outbreak of the early 1960's. Intense crown fires occurred in areas where the forest stands were uncut, chiefly during the first run of the fire. Among the many complicating weather factors that existed during this fire were the wind shifts and high velocities associated with rapid frontal movements through the area.

The light rain shower that occurred the morning of May 15 prevented the fire from burning a much greater acreage. The fire could have been three or four times as large if precipitation had not wet the fine fuels at that time.

Fire control operations were hampered by the inaccessibility of much of the fire perimeter and the extensive spot fires that occurred throughout the area. Springtime conditions made vehicular travel impossible over many of the logging roads within the burn area. It was only after all-terrain vehicles were obtained and more favorable weather conditions slowed the spread of the fire that control operations became effective.

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